key to the solution of the problems in the physical chemistry of geology lies in the determination of the conditions of equilibrium of each set of actions, or states of existence, of the factors under discussion; and further that he has attempted rather to stimulate interest in this branch of geology than to provide a complete exposition of the subject. It appears that this attempt is eminently successful, and that students of geology and petrology will be greatly benefited by this presentation of the principles in question.

The book consists of 10 chapters dealing with (1) Equilibrium between the Crystalline and Amorphous States; (2) Equilibrium as Influenced by Viscosity; (3) Diffusion as a Factor of Equilibrium; (4) Surface Tension as a Factor of Equilibrium; (5) Vapor Pressure as a Factor of Equilibrium; (6) Equilibrium Conditions of Polymorphous Forms; (7) Equilibrium in Solutions; (8) The Eutectic Theory; (9) The Theory of Solid Solutions Applied to Geological Problems; (10) On the Conditions of Chemical Equilibrium in Geology.

Without undertaking to give a synopsis of the contents of these chapters, or to do more than express approval of the method of treatment with a recommendation that they be carefully studied by those interested in the subject, attention may be called to several instances in which the fallibility of the literature relied upon by the author may be illustrated, or to instances where it has been misinterpreted. In the Chapter on Viscosity the observation of Barus on the combination of water and glass at temperatures between 185° and 200° C. is cited, and the impression is given that it is an operation of unlimited applicability to all glasses. Whereas Barus subsequently found that other commercial glass did not combine with water under any conditions which his apparatus was able to impose. The general conclusion stated by Mr. Elsden as to the effect of water in solution in silicate magmas in reducing viscosity is, nevertheless, correct, as other observations have shown.

In connection with surface tension and its explanation of the growth of larger crystals at the expense of smaller ones the author has confused his citations by referring to a description of the obsidian at Obsidian Cliff, Y. N. P., by the reviewer, as containing a supposed application of the principle to the weathering of the laminated rock. There is no reference to weathering in the paper mentioned, and its author never entertained any such ideas as those implied in the comment by Mr. Elsden.

In the discussion of crystallizations in metastable and labile states of solution it is quite evident that the author is not relying on his own knowledge of rocks, but has been misled by the dogma of "first and second generations of crystals," when he states that "while the metastable state persists small crystals could not be produced," for nothing is commoner than seriate porphyritic fabric in igneous rocks, and the presence of various sized crystals of the same kind of mineral. His treatment of the subject of crystallization is not so satisfactory as that of other portions of his subject. And in the discussion of the amphibole and pyroxene series the lack of appreciation of the chemical phase of the problem is apparent.

Aside from these criticisms the book is a valuable contribution to the literature of geology, and should be studied by all who desire to understand the bearing of physical chemistry on the problem of the formation and alteration of minerals and rocks.

J. P. IDDINGS

THE RELATION BETWEEN THE COLORATION AND THE BATHYMETRICAL DISTRIBUTION OF THE CYCLOGASTERIDÆ

IN a recent article in SCIENCE[1] Dr. H. B. Bigelow gives a résumé of a preliminary report[2] by Dr. Johan Hjort on the results of the

[1] July 7, 1911.

[2] *Geographical Journal*, Vol. 37, 1911, pp. 349–377, 500–523. Not seen by the writer.

Michael Sars North Atlantic expedition in 1910. Dr. Bigelow cites, as one of the important results of the expedition, the experiments undertaken to discover the depth to which sunlight penetrates below the surface of the ocean and the relation between this and the bathymetrical distribution of animals exhibiting certain types of coloration. Dr. Hjort found that the red rays are absent and the blue and violet rays present at 500 meters; at 1,000 meters ultra-violet rays are perceptible and at 1,700 meters no trace of light could be detected. The black fishes and red prawns taken in the daytime in temperate latitudes were from a depth of 500 meters or more, *i. e.,* below the penetration of the red light rays. In more northern latitudes these animals were taken nearer the surface. In these regions the red light rays probably do not penetrate so far below the surface. Above the 500-meter level the fishes were found to be "characterized by lateral compression, larger and often telescopic eyes, light organs and silvery sides." These facts led Dr. Hjort to suggest that the lower margin of the area penetrated by red light rays marks the border between two differently colored faunas. Dr. Bigelow, in support of this view, states that the *Medusæ* apparently can be divided into two color groups which overlap at 250 to 300 fathoms. The species above this level are characterized by little pigment and iridescence, and those below by red and brown pigment.

The same relation between the vertical distribution and the coloration was found to exist in the young. The young of some of the species spend their larval existence near the surface and do not exhibit the adult coloration, this being acquired as they increase in size and descend to the habitat of the adult. The young of other species develop in the same region in which the adults are found and acquire the adult coloration much earlier. The coloration and vertical occurrence are correlated from the earliest stages.

The writer, during the preparation of a monograph of the Cyclogasteridæ, has had occasion to trace out the correlation between the coloration and the bathymetric distribution of these fishes. The results obtained are of interest in connection with those obtained by Dr. Hjort and Dr. Bigelow and it seems opportune to present a general account of them in advance of the main body of the work.

In reviewing the results presented here it should be borne in mind that the records upon which they are based are very incomplete when compared with those available to Dr. Hjort. It should also be noted that Dr. Hjort's conclusions result from the study of the general fauna while those of the writer are based upon the examination of a single family. This may account for the difference in the conclusions arrived at. The methods employed by the *Albatross* are very unsatisfactory for the solution of problems dealing with vertical distribution. The dredge is sent down and hauled up open, catching forms through all the intervening depths. Unless the animals captured have some peculiarity of structure which indicates their habitat as being on the bottom it is impossible to decide at what depth they entered the dredge. The intermediate hauls are made at a depth of 300 fathoms and the net hauled up open. The absence of species from the intermediate hauls indicates that their habitat is below this depth, but how far below remains a mystery. Also records of the coloration of the fishes, as they first appear, are very seldom taken. The colors frequently change in spirits. The translucent reddish cyclogasterids usually become an opaque white. This restricts the conclusion that can be drawn from the study of such specimens.

The Cyclogasteridæ is a favorable group in which to work out the modifications of structure and color as the species become adapted to the deep sea. This is true because the family is abundantly represented at all depths from the tide pools down to 1,973 fathoms. About 42 species are known to inhabit depths of less than 100 fathoms, 49 inhabit the region between 100 and 500 fathoms and 34 the depths greater than 500 fathoms. Starting with the tide-pool species as the most primitive, we can readily trace out definite modifi-

cations of form, structure and color as the species became more and more modified by the environment of the deep sea. We will confine our attention to the modification of the coloration and the relation between this and the distribution of the species.

The Cyclogasteridæ consist of about 100 species. The majority of these are placed in three large genera. The genus *Cyclogaster* consists of about 30, *Careproctus* of 38 and *Paraliparis* of 21 species. The remaining genera are monotypic or consist of a few species. The vertical distribution and the coloration of the three large genera will be described first. This will be followed by a chart indicating the distribution and coloration of all the species of the family.

Before entering upon a discussion of the genera it is advisable to review briefly the factors which lend color to the different environments inhabited by these fishes. For our purpose the color of a tide-pool environment may be said to be due to three factors or groups of factors. These are: (1) sunlight, (2) organisms and their remains, (3) inorganic materials of which the bottom is composed. In the tide-pools the coloration of the second factor may appear to depend upon the other two factors. In the oceanic depths below the penetration of light and far above the bottom these two factors are absent. The color of the organic life, if protective, can not be dependent upon their influence. It is necessary to assume the presence of light other than sunlight. We know that there is such light as can be produced by light organs. It has been suggested that there is another source of light on the bottom of the ocean. The decomposing animal matter may give off a phosphorescent glow of such intensity that the large-eyed fishes may be able to detect objects.

The modification of the color factors of the environment is accompanied by a modification of the coloration of the fishes. The sunlight is more intense and the organic life more brilliantly colored in the tide-pools and shallow waters of the tropics than in the arctic regions. The difference in the intensity of the sunlight is accompanied by a difference in temperature, but we shall ignore all the factors which compose an environment except those that exhibit color. As we descend below the surface of the ocean the sunlight becomes less intense. The organic life becomes less brilliantly colored. The red light rays probably do not penetrate below 500 meters or 273 fathoms. It has been suggested that this depth marks the border between two differently colored faunas. Dr. Hjort found that the fishes above this depth are characterized by silvery sides and those below by black pigment. The black forms are found nearer the surface in northern latitudes. Where the 273-fathom level touches bottom and where it is far above bottom constitute two differently colored environments. If at this level the color of the bottom has an influence, then the color of the fishes inhabiting these two environments should be different. It will be shown on the following pages that the bottom-inhabiting species of cyclogasterids appear to be differently colored from the free-swimming forms. There is a certain depth in the ocean below which light fails to penetrate. This will be less in the arctic than in the torrid regions. Its importance in marking the region between two faunas remains to be carefully worked out.

Cyclogaster is a shallow water genus. The species are common in the tide-pools and shallow cold waters of the northern and southern hemispheres. At least 21 of the 30 species have been taken in less than 10 fathoms. Only 5 species have been taken from depths below 100 fathoms and 3 from below 200 fathoms. One specimen has been taken at 250 fathoms. It is thus seen that the genus is confined to the illuminated area of the oceanic waters. We may provisionally place the lower margin of the bathymetric distribution of the genus at the level at which Dr. Hjort found the red light rays absent, the 500-meter or 273-fathom level.

The species of the genus, with but three exceptions, have a similar type of coloration. The colors harmonize with those of the other shallow-water fishes of northern regions. The

species typically have a variegated coloration which consists of bars, blotches, lines and mottlings of white, slate, brown and black, the predominating colors of the fishes of northern regions.

The coloration of the deeper-water species is slightly modified by the environment. The variegated coloration is retained, but in addition to this, in two or three species, a reddish lining to the dermis and a silvery or a black peritoneum have been acquired. These are the colors predominating in the genus *Careproctus* which flourishes in regions between 100 and 500 fathoms. The vertical distribution of each species is important in considering its coloration. Species such as *Cyclogaster dennyi* and *Cyclogaster fucensis,* which extend from within 2 or 3 fathoms of the surface down to 123 and 212 fathoms, do not show an appreciable change in coloration.

Careproctus is the most interesting genus in the family. It has been derived from the shallow-water genus *Cyclogaster* and presents the first distinct modification of structure and color caused by the environment of the deep sea. It has given rise, directly or indirectly, to practically all of the other deep-sea genera. The distribution of the species extends from shallow water to great depths, or from 29 to 1,823 fathoms. The genus seems to flourish best in the region between 100 and 500 fathoms. Two thirds of the species are found in this region.

The coloration of species of *Careproctus* is very distinct from that typical of the species of *Cyclogaster.* None of the species are variegated. The nearest approach to this condition is that of *Careproctus cyclospilus* and *Careproctus mirabilis,* two shallow-water species, which have pink blotches over the body. The species are typically translucent, reddish translucent and black. In a number of species the posterior part of the body only is black. It appears that the black pigment encroaches upon the body from the caudal region anteriorly.

The species of *Careproctus* can be arranged in three color groups. These groups include the light-colored species, the black species and the species intermediate between these two. The light-colored group includes the translucent, whitish and reddish species. When placed in alcohol the translucent and reddish appearance is usually lost and the species become an opaque milky white. It is doubtful if any of the species are this color in life. In the black-colored group are included all the black species. In the third group are included those species which are dusky or have the posterior part of the body, the gill cavity, peritoneum or stomach black. The distribution of these three color groups will be considered separately.

The light-colored group, consisting of 27 of the 38 species of the genus, is represented in depths between 29 and 1,046 fathoms. The majority of these species are found between 100 and 500 fathoms. Six species are found in less than 100 fathoms and 4 below 500 fathoms. The distribution of the light-colored species apparently has no more relation to the 273-fathom level than to the 400-fathom level. Eighteen species are found above the 273-fathom level, 13 below it and 4 on both sides, while 22 species are found above the 400-fathom level, 10 below it and 5 on both sides.

The distribution of the remaining two groups of species does not indicate that the 273-fathom level marks the border between two differently colored faunas. The dusky species, of which there are 8, are found between 35 and 887 fathoms, but the majority have been taken between 300 to 500 fathoms. There are 3 species in the black group and these are all from below 405 fathoms.

The color of the peritoneum is of interest in connection with the color of the body and the distribution. The peritoneum is sometimes black when the epidermis is white, but apparently is never white or silvery when the epidermis is black. In preserved specimens it is sometimes difficult to decide whether the peritoneum was originally a dull white or silvery. It appears, however, that the silvery peritoneum is most common with the reddish translucent species. Dr. Hjort reports that the fish fauna above the 273-fathom level is characterized by silvery sides. A silvery

peritoneum in the translucent species of *Careproctus* gives these fishes somewhat the appearance of having silvery sides. The distribution of the species having a silvery peritoneum apparently is not influenced by the change in environment at the 273-fathom level.

The facts concerning the coloration and distribution of the species of *Careproctus* indicate that the 273-fathom level is of no greater, if of as great, importance than the 400-fathom level in marking the border between two differently colored faunas. The former level appears to be of little or no significance in the distribution of the light-colored species, while the latter level marks the upward limit of distribution for the black species and contains the largest number of species intermediate between white and black, *i. e.*, the dusky species.

The genus *Paraliparis* in structure, coloration and distribution is more of a deep-sea genus than *Careproctus*. The species of the genus may be placed in three color groups, but the proportion of the species in the groups differs from that in *Careproctus*. For instance only 8 per cent. of the species of *Careproctus* are black while 50 per cent. of the species of *Paraliparis* are of this color. All the species of *Paraliparis* have a dusky or black peritoneum. Only 25 per cent. of the species *Careproctus* have the peritoneum black. The species of *Paraliparis* typically inhabit greater depths than do the species of *Careproctus*. The high and low levels of distribution for the two genera are almost identical, but what may be termed the centers of population of the two genera differ. Half of the species of *Careproctus* are taken above and half below the 300-fathom level. The 500-fathom level holds the same relation to the distribution of the species of *Paraliparis*. We thus see that there is a difference of 200 fathoms between the centers of population of the two genera. There must be considerable difference in the amount of light present at these two centers of population. With this difference in the amount of light is associated the difference in the number of black forms in the two genera.

The relation between the coloration and the distribution of the species of *Paraliparis* is the same as in *Careproctus*. Without entering into much detail we will state that the 273-fathom level is of no significance in the distribution of the light-colored species. Only two of these species have been taken below this level. The distribution of the black species is interesting because, as in *Careproctus*, it extends from 400 fathoms downward.

The distribution of all the species of the family reinforces the conclusions that may be drawn from a study of the distribution of the species of the genus *Careproctus*. The chart indicates the coloration and distribution of all the species. It can be seen that the 273-fathom level marks the lower limit of distribution for the variegated species, but is of no significance in regard to the distribution of the light-colored, dusky or black species. The region at about 400 fathoms is of more importance. It marks the depth at which the light-colored species are reduced in numbers, and where the dusky species are the most common. It also marks the upper limit of distribution of the black species.

Depth	30	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Variegated	23	11	4	3																	
Light	1	7	10	15	12	11	4	4	1			1									
Dusky		2	8	7	11	11	7	6	3	2	2	1	1	1	1	1	2				1
Black						3	2	3	1	2	3	3	1	1	1	1	2	1	3	3	

Chart illustrating the coloration and bathymetrical distribution of the Cyclogasteridæ. Species ranging through depths represented by several sections are counted in each section.

The facts just stated indicate that, in general, the coloration of the species of *Cyclogasteridæ* depend upon their bathymetrical

distribution. The question naturally arises: are these fishes protectively colored, or, is the color dependent upon the modification of structure or some other factor besides the color of the environment? The question is complex, because there is a parallel modification of color and structure due to the environment of the deep sea. It frequently happens that a certain type of structure is associated with a certain type of coloration. Also the coloration of the species sometimes appears to be independent of either the color of the environment or the type of structure. Those biologists who view with suspicion the attempts to explain the coloration of tide-pool fishes by means of the protective coloration theory will be even more skeptical toward any effort to explain the coloration of deep-sea fishes by means of the same theory. The factors of a tide-pool environment are spread out before us but those of the deep-sea are hidden. We do not know that there is sufficient light in the greater depths of the ocean to enable the fishes to see and of course without light there can be no protective coloration. If this is a region of total darkness the color of an animal can not be an aid to its concealment. So far as protection is concerned a fish may just as well be brilliantly colored as transparent or black. But they are not brilliantly colored. Instead they are typically of a uniform coloration, which is usually black. In the regions of dim light they are of another color. The coloration bears some relation to the depth at which the species exist. The amount of sunlight depends upon the depth and consequently the coloration appears to depend upon the amount of sunlight to which the species are subjected. There are two possible sources of light in the oceanic depths below the penetration of sunlight. We know that certain animals of this region have light-producing organs and the decomposing animal matter may give forth a phosphorescent glow. And, as if for the purpose of sight in a dim light, the eyes of the fishes have become greatly enlarged. Regardless of the merits of the protective coloration theory it furnishes us with a fascinating field for speculating. The attempt to explain some of the facts concerning the coloration of the Cyclogasteridæ by the protective coloration theory will not be amiss here.

The environment of the deep sea has had a different effect than the dark cave environment upon fish life. Dr. Eigenmann has made an exhaustive study of cave fishes. In these fishes the eyes atrophy and the pigment is reduced or absent. Dr. Eigenmann believes that we have here an example of the inheritance of an acquired characteristic. The case, as he so ably presents it, appears unassailable. The color of some of the cave fishes can not be protective, for there are no enemies to protect them from. The fishes of the deep sea are surrounded by other fishes with large eyes and long teeth. The presence of a light would allow the struggle for existence to become more intense. The effects of a cave environment and the deep-sea environment upon the coloration of fishes are similar up to a certain point and then widely diverge. The effects of the dimly lighted cave and the dimly lighted regions of the ocean lead to the reduction of pigment. The effect of a totally dark cave is to allow the fishes to lose all their pigment. In contrast to this the fishes in the ocean below the penetration of sunlight acquire pigment and become wholly black. Possibly the difference in the effects of the two environments can be explained by the protective coloration theory, which can not explain the coloration of cave animals but may explain the coloration of deep-sea animals.

The overlapping of faunas calls for further discussion if we are to consider the fishes as protectively colored. The genus *Careproctus* originated in moderately deep waters. From this region representatives of the genus migrated into shallower waters and down to great depths. Those that entered shallower waters retained their light and uniform coloration. Of those that descended to greater depths some retained their original coloration, but the majority became black. The species that entered shallow water became associated with the variegated species of *Cyclogaster*. The distribution of these two genera overlap be-

tween 29 and 250 fathoms. The association of species of the two genera may be more apparent than real, for the species of *Cyclogaster* are typically bottom-inhabiting forms and those of *Careproctus* free-swimming. The distribution of the light-colored and black forms overlap between 400 and 1,000 fathoms. The gradual merging of one environment into another and the force of heredity may account for the overlapping of the faunas, but, as is the case with the shallow-water species, the differently colored ones may not intermingle. Let us imagine a portion of the ocean bottom as illuminated by a lantern. A black fish on a dark bottom or near the margin of the illuminated area would be practically invisible. A transparent or a reddish translucent fish would be little more discernible. Away from the bottom and near the source of light a black fish would be more conspicuous than the others. At such depths it is difficult to decide which species rest upon the bottom and which swim freely some distance above it. The deep-sea Cyclogasterids, which, from their structure, we assume to be free-swimming, are nearly all light-colored. Nearly all of those which appear to live upon the bottom are black. It should be noted that among other deep-sea fishes a number of free-swimming species are black and also that some of the bottom-inhabiting species may be light-colored. It can be seen from the above discussion that the light-colored species in the depths below the penetration of sunlight may be as protectively colored as the black forms. The disparity in the numbers of light-colored and black species suggests that this is not true or that the majority of the species live upon or very close to the bottom.

The significance of the predominance of reddish color in the light-colored species is unknown. This type of coloration may be considered as being intermediate between the translucent and black types and having the partial advantages of both. In dealing with this question the color perception of the eyes of fishes should be taken into consideration. If the eyes of fishes lack the color perception of our own and are simply camera eyes the reddish species will appear gray and be inconspicuous in their environment.

We have intimated that, in addition to a change in coloration, the deep-water species become translucent. The tide-pool species are soft and flabby and no great change is required for them to assume a translucent jelly-like appearance.

In concluding I wish to express my appreciation of the work of the *Michael Sars* in 1910. The observation made on this expedition that the coloration and bathymetrical distribution of the young fishes are correlated from the earliest stages is confirmed by my work on the Cyclogasteridæ. The young of these fishes inhabit the same regions as the adults and are similarly colored. Dr. Hjort's suggestion that the 500-meter or 273-fathom level marks the border between two differently colored faunas does not harmonize with the conclusions I have reached from a study of the Cyclogasteridæ. The acquisition of more carefully taken records of these fishes resulting from expeditions as carefully planned as that of the *Michael Sars* may cause us to modify our conclusions concerning the importance of the 273-fathom level in relation to the distribution and coloration of the Cyclogasteridæ and bring them more in accord with those of Dr. Hjort.

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SPECIAL ARTICLES

ISOSTASY, OCEANIC PRECIPITATION AND THE FORMATION OF MOUNTAIN SYSTEMS

THE theory of isostasy postulates the uniformity of the weight of the earth's crust over the surface of the earth. It was suggested by Major Sutton[1] in 1889. It has recently received considerable attention by geodesists and geologists and has received quantitative confirmation by the researches of Hayford.[2] Recent work has been along the line of investigating the effect of displacement by erosion and the resulting equilibrium flow.

[1] *Bull. Phil. Soc. Washington,* 11: 51–64, 1889.

[2] See SCIENCE, February 10, 1911; also H. F. Reid, *Proc. Am. Phil. Soc.,* 50: 444–451, 1911.